AMYGDALA $z \mapsto z^2+c$

A Newsletter of fractals & $\mathcal{M}$ (the Mandelbrot set)

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CONTENTS

THE SLIDES

Those subscribing to the color slide supplement now have the second four slides of the current series of 24 slides.

502. Ken Philip: The 'pinwheel' at the center of the 'galaxies' at 100,000x, ER = 2. The galaxies form a tiny blob on a Seahorse Valley tendril at 10,000x. The name refers to the fact that these blobs tend to look like spiral galaxies when seen with a 'smooth' CLUT.

909. James E. Loyless. *Turquoise Belt Buckle*. This is a dragon that resides in one of the floater baby bugs ("Island Molecules") that occur at intersections in the lacy filigree of a Shepherd's Crook type spiral. My shot that showed up in Dewdney's column is the inner third of this beast.

1022. John Dewey Jones: The Julia set generated by a seed (-0.776,785,376+0.135,763,53i) taken from the center of Buddha's Garden, over the region of the plane given by:

$|\mathrm{Re}(z)| \leq 1.7, |\mathrm{Im}(z)| \leq 1.0.$

I've used the conventional escape radius of 2, rather than the mysterious process Fitch used to produce his 'petals'.

1023. John Dewey Jones: A subset of 1022 lying within the region for which the real and imaginary parts of z differ by not more than 0.001 from the Re & Im of the seed. Note that the little Mandelbrot in the middle of the garden has changed into a peculiar two-headed Mandelbrot, rather like that obtained by iterating on $z \mapsto z^3 + c$.

"NOTHING BUT ZOOMS"

Nothing But Zooms is a video produced by Art Matrix on the supercomputer facility at Cornell. It consists of 30 minutes of eleven mind-blowing colorful trips into the Mandelbrot set, which used over $40,000 of supercomputer time to create. The zoom sequences are accompanied by synthesizer music scored explicitly for this video, by turns sprightly, comic, pompous, but always apposite.

Each of the trips consists of a zoom toward a specific point near the Mandelbrot set.

1. The target of the first zoom sequence is a point near a bud on the zipper in the south crevice between the head and the topknot of the Mandelbrot set (see Amygdala #5, page 2). A yellow prominence becomes the end of a yellow archipelago in the midst of a blue sea. Further expansion reveals a tiny $\mathcal{M}$ surrounded by golden spirals: 8 of them ... 16 ... 32 ... A tiny $\mathcal{M}$-jewel in a gold setting.

2. The target is the extreme tip of the branch near -0.2+1.1i. The zoom is apparently an attempt to elucidate the structure of the extreme tip. Like the effort aimed at -2.0 in "A Journey to the West" (Amygdala #5, page 2) this effort to discover the structure of the singularity at the branch tip is thwarted by a comical and illuminating evasion. The effort to "see" the tip of the branch reveals a twig, angled 30° counterclockwise of the parent branch. In and in we bore: nothing appears but a series of twigs, each expanding to a branch, the next twig merely rotated 30° CCW from the parent, ghostly shrouds of blue being cast off ... On and on until a full circle of futility is achieved.

3. The target is on the north arm bud, the left crevice between it and the main body ... a tiny zipper bud on the body ... eyes and a seahorse tail ... in, to the lower left of the eye,

center to one of the ants making up a spiral arm, background yellows and blues explode into view ... headed toward the tiny expanding end of a tiny seahorse curl.

4. In toward the utter West, blue left, white right ... toward a midget ... eight white petals. The spike of the midget ... a midget on the spike ... toward an even smaller midget ... vaulted blue and white arches ... an $\mathcal{M}$ surrounded by white rays. Beautiful!

5. A new view of the journey undertaken in #4, showing the details not as colors only, but as elevations on a topographical map, magenta $\mathcal{M}$s appearing as rainclouds floating above the ground, raining down into the heart of an active volcano.

6. Starting at the archipelago of #1, zooming into a golden double spiral — not to its center, but to a structure on one arm, a quadruple spiral expanding from a violin-f, in the center a tiny replica of the outer structure, but an 8-spiral and, inevitably, another tiny $\mathcal{M}$ in the molten crucible's heart.

7. To the strains of a harpsichord, the north crevice between body and head (?). The main body zipper, bud, eye and seahorse tail ... blue and orange. In toward the eye ... a blot at its center, unresolved at the iteration limits used, and probably unresolvable. Splendor of seahorse tail and spiral arms.

8. Carnival music accompanies a journey starting at the dual crevice south. A bud on the head ... heads of grama grass like question marks — a faster zoom this time. Buds within buds, each radiating grama heads. In to a double spiral grama head. In and in toward the heart of the spiral ... Off toward one of the sides, ... finally an f with quad arms.

9. Starting with the Big Picture; centered on the south crevice between body and head. In to a sub-sub bud on the bud ... A seahorse tail, blue against pale yellow-green. A tiny tail on the tail, an orange sun below. Tails on tails on tails ...

10. Another crevice, north, between body and head? Moving in toward a bud on the body ... toward a crevice north on the bud ... a hawk's head and upper body ... similar substructure ... sub sub sub ... Elephant trunks ...

> So, Nat'ralists observe, a Flea
> Hath smaller fleas that on him prey;
> And these have smaller fleas to bite 'em,
> And so proceed *ad infinitum.*
> —*Jonathan Swift*

11. Starting once more with the Big Picture. The south crevice between body and head ... a bud in the body zipper, scintillating pale yellows and blues ... a sub-crevice between bud and body ... a seahorse tail ... black blots in the interior of the tail ... a central $\mathcal{M}$ in a shimmering setting.

...

This marvel is available from Amygdala for $25.00, postpaid. Specify VHS or Beta.

MACINTOSH II MANDELBROT PROGRAMS

Ken Philip

(Part 2)

We conclude the article begun in Amygdala #11.

To summarize, on the page opposite is a table showing the main features of all seven programs, for rapid comparison. All of the features in the table are then discussed in more detail.

Discussion of Features

Maximum Magnification: Much of the fascination of the Mandelbrot Set comes from the ever–increasing and subtly changing details that are revealed as you increase the magnification at which you view the set. The higher the limiting magnification of the program, the longer you can play this game—so the useful limit of magnification is an important parameter of any Mandelbrot program. This limit may be imposed in a number of different ways. In MANDELCOLOR, the box in which coordinates are displayed and entered limits the numbers to 10 decimal places. If the left/right or top/bottom limits do not differ by at least 1 digit in the tenth place you will get an error message—cutting off magnification sharply at about 30 billion diameters. MANDELBROT 2.7 also cuts off the coordinate display at 10 decimal places, but the program will continue to function up to over 10 quadrillion diameters. Other programs which can accept more decimal places (MANDELBROT MICROSCOPE, ANI–MANDEL, MANDELZOT) will eventually fail due to truncation errors in the mathematics. In order to calculate the iteration values for each screen pixel, the program takes the length of a side and divides it by the number of pixels in that coordinate. If truncation ensues, all subsequent calculations will actually refer to the same pixel, and the screen will come out all one color. With the precision of the 68881 math chip, this kind of truncation error appears to limit magnification to the low quadrillions (about the same as the program FRACTAL MAGIC on the IBM PC). Some programs will develop anomalous behavior before the actual hard truncation limit is reached: MANDELBROT MICROSCOPE suffers a breakdown of the relationship between the displayed corner coordinates and the screen image at around 10 quadrillion diameters. Programs like MEGABROT, or MANDELZOT, which offer a choice between fixed point and floating point computations, will exhibit different magnification limits for each type of computation (but for some strange reason MEGABROT seems unable to go beyond 8 million diameters in its floating point mode, and exhibits anomalous behavior at that relatively low magnification). Note: the magnification limits listed are somewhat arbitrary, being determined by the point at which truncation errors seriously affected image quality. Visible truncation effects may set in well before the listed limit. Also, the measurements were made along the 'spike', on the real axis, since that is a region in which one can push (for some programs) coordinate reporting (along the imagin-

Table of Macintosh II Mandelbrot programs

	Mandel8	MandelClr	Megabrot	Man. Micr.	Ani-Mandel	MandelZot	Man. 2.7
Max mag[1]	100×10^6+	30×10^9	8×10^6	10×10^{15}	30×10^{15}	30×10^{15}	30×10^{15}
Max dwell	999	240	4095	4096	$>10^4$	4095	1024
Escape rad.	2	10→1000	2	2	2	2→	2
Speed[2]	12.5	25.6	26.0	27.9	30.5	23.2[3]	27.1
Animate	No	Yes	No	No	Yes[4]	No	No
Selection	drag	drag/#	drag/#	drag	#	drag	drag/#
Coord rep.	5 place	10 place	8 place	9 place	8 place	→18 place	10 place
Size	→Full Scn	→Full Scn	400x400	400x400	Full Scn	→Full Scn	450x450
# colors	~64	→240	63	6/254	→254	14	→254
adj color?	No	2 CLUTS[5]	Yes[7]	Yes[6]	Yes[6]	No	Yes[7]
M Set color	Black	Black	Black	White	Black	White	Any
Save image	Yes[8]	Yes	No	No[9]	No	Yes	Yes
Save palette	No	No	No	Yes	No	No	Yes
Mult. wndw	Yes	Yes	No	No	No	Yes	No
Bkgnd/MF	No	Yes	No	No	No	Yes	No
Refresh	Yes	Yes	No	Yes	Yes	Yes	Yes
fixed r/i	No	Yes	Yes	Yes	Yes	No	Yes
Julia Set	No	No	No	No	Yes	No	No

1 Measured on the real axis (the 'spike'). Maximum magnification may be much lower off the real axis.
2 Pixels/second at dwell of 1000 in 80-bit floating point.
3 'DivCon' algorithm multiplies this basic speed by 3 or more times.
4 CLUT animation may be stopped, reversed, and single-stepped.
5 One 'rainbow' CLUT and one 'contrast' CLUT.
6 Individual colors in CLUT may be altered with Color Picker.
7 Colors may be altered both individually and in selected ranges.

ary axis) to higher precision. For some of the programs with the highest magnification capability, limits may be lower by a factor of 100 or so for points off the real axis, judging by a test on MANDELBROT MICROSCOPE (which reports the distance between pixels in scientific notation, allowing the magnification to be determined at any point in the complex plane).

Maximum dwell: High magnification is useless in regions close to the boundary of the Set unless you have access to high dwell limits as well. The limit of 240 to the maximum dwell in MANDELCOLOR is a severe limitation to the utility of this otherwise excellent program at the higher magnifications of which it is capable. To work far down into Seahorse Valley requires a dwell of at least 1000 or so, for instance. Many high magnification plots I have made using MANDELCOLOR display large black areas where the low dwell limit has concealed structures by including them inside the Set. Programs that can use magnifications in the quadrillions should have a maximum dwell limit of the order of 1000 (if not greater), a criterion which is met by all the remaining programs.

Escape radius: The shape of the contours (especially along the spike) is controlled by the value of the 'escape radius', which is the value for the magnitude of the complex number that is tested for in the iteration process and used as a criterion for whether a pixel lies within the Set, or outside of it. Most of these programs use an escape radius of 2 (which means they are testing for $\mathbf{z}^2 > 4$). This value produces a characteristic 'infinity sign' pattern to the contours along the spike. A more physically meaningful escape radius is any value large compared to the diameter of the Set. If a value of 100 is used, the test is for $\mathbf{z}^2 > 10{,}000$, which requires only 3

or 4 additional iterations per pixel—and now the contours represent equipotential lines if one were to imagine that the Mandelbrot Set bore an electrical charge. Along the spike the contours now run parallel to the spike, moving outward around midgets rather then diving in towards them. Two programs, MANDELCOLOR and MANDELZOT, allow the escape radius to be varied, but MANDELCOLOR imposes a minimum value of 10. MANDELZOT is thus the only program in this group that will allow the user to directly compare the effects of a radius of 2 and one of 100. An ideal Mandelbrot program would allow free variation of the escape radius by the user, as well as allowing the 'escape region' to have other shapes than circular (in which case the escape radius would refer to some average dimension of the region).

Speed: All of these programs use direct access to the 68881 (some coded in assembly) for floating point speed. In order to have a meaningful speed comparison index, the speeds in the table are expressed in the number of pixels computed per second at a dwell value of 1000, regardless of whether the program can attain a dwell that high, or set its maximum dwell precisely to 1000. MANDELCOLOR is limited to a maximum dwell of 240—but the ratios in the table should hold roughly for all the programs at any given dwell. MEGABROT has a 32–bit fixed point mode and a 16–bit fixed point mode, which are respectively about 1.8 and 2.3 times as fast as the 80–bit floating point mode. MANDELZOT also has fixed–point modes, but in addition has the Mariani/Silver 'DivCon' algorithm which provides a speed increase of 3 or more times in the 80–bit mode.

Animation: It is possible to write a routine which rapidly cycles through the CLUT, replacing each color with the adjacent color. This routine will produce a striking effect on the screen image—all the color bands quickly move up (or down) the 'slope' of the run of iteration numbers. In spiral structures the color bands swirl into the center in an almost hypnotic fashion. MANDELCOLOR has this animation feature, but in one direction only (*up* the run of iteration numbers)—and a click on the mouse stops the animation and instantly returns the screen to its starting colors (thus not allowing you to save or photograph the screen as affected by animation). ANI–MANDEL, on the other hand, has animation in either direction—and the animation may be stopped in place, and single-stepped in either direction. The resulting image may then be photographed, or archived with a color screen–save utility like Palomar Software's Colorizer.

Selection: The most 'Maccish' way to select the area for the next plot is to drag a rectangular box around it with the mouse, and then expand the contents of that box to cover the screen on the next plot.. Most of these programs use this method of selection, but some also allow the user to type the corner coordinates into text–entry fields (or one corner and side length: MANDELBROT 2.7). One program (ANI–MANDEL) does not allow selection by mouse at all, and does not use corner coordinates either. In this program you enter the *center* coordinates, and the length of the side (not specified as to horizontal or vertical side) of the plot rectangle into text entry fields. The mouse *can* be used to obtain the coordinates at the lower ranges of magnification: a click on a screen pixel with the Option key depressed will post the coordinates of that pixel to the upper left corner of the screen, where they are available for typing into the text entry boxes.

Mapping a rectangular box to the screen involves the possibility of distortion, should the aspect ratios of the screen and the rectangle be different. MANDELCOLOR forces the aspect ratio to be correct even if it means cutting down the coverage along two opposite edges of the rectangle. Two programs (MANDEL8 and MANDELZOT) allow distortion of the image, so it is the user's problem to make sure that the aspect ratio of the selection rectangle matches that of the plotting window on the screen. MANDELBROT MICROSCOPE, MEGABROT and MANDELBROT 2.7 solve this problem by plotting in a fixed-size square, and forcing the selection rectangle to be square.

Coordinate reporting: All of these programs have some means of letting you know the actual coordinates of the image in the complex plane. The table entry gives the number of places to the right of the decimal point used in the coordinate listing, which relates to the maximum magnification at which you can easily find the coordinates of the image. Most programs will allow you to magnify the image far beyond the program's ability to report your location, except for MANDELCOLOR (which cuts off at 30 billion diameters, at the last digit in the coordinate display) and MEGABROT (which inexplicably cuts off at 8 million diameters despite its 8–place coordinate diplay). Two programs (ANI–MANDEL and MANDELBROT 2.7) allow you to *enter* coordinates and plot to them to higher precision than they *display* the same coordinates.

Size: For maximum resolution in the image, the plot should be made to the full screen. Most of these programs allow full screen plotting, but MEGABROT and MANDELBROT MICROSCOPE plot to a 400x400–pixel square region on the screen, and MANDELBROT 2.7 plots to a 450x450–pixel square. This is a disadvantage if you plan to photograph the screen, since the aspect ratio of a 35mm slide (0.68) is actually smaller than that of a 640x480–pixel screen (0.75), let alone a square. With a square plotting area, only 68% of that plot can be imaged on a slide, reducing the final resolution to 272x400 pixels, while for the full screen a slide can cover 435x640 pixels.

It is also useful to be able to make trial plots to a small window, since the plotting time is directly proportional to the area (# of pixels) being plotted. MANDEL8, MANDELZOT, and MANDELCOLOR allow you to plot to a small window at will, while ANI–MANDEL plots to a fixed full–screen window only. MANDELBROT 2.7 takes a different approach, allowing you to plot to its fixed-size window at lower

resolution for faster plotting.

Number of Colors: The Macintosh II, equipped with an 8-bit video card, can display up to 256 colors at one time (of which 2 are black and white), selected from a palette of 16.7 million colors. By 'color' is meant a particular value of hue, saturation, and intensity—so 254 intensity levels of a given hue and saturation would count as 254 different colors, and so would 254 different hues of the same intensity and saturation, and any other set of 254 different values of the 3 parameters involved.

Five of these programs can put up 240 or more different colors—the other two (MEGABROT and MANDELZOT) are restricted to 63 and 14 colors respectively. An earlier version (0.5) of MANDELZOT could put up 52 colors—but that version did not access the math chip and was thus very slow.

Adjust Colors: In order to bring out the structure within a Mandelbrot Set image the colors should be adjustable by the user, since no single progression of colors will serve to highlight interesting features at all possible values of magnification and maximum dwell. These programs fall into four categories as regards their color adjustment capabilities:

1. No adjustment (MANDEL8).
2. Switching CLUTs (MANDELCOLOR, MANDELBROT MICROSCOPE, MANDELZOT). MANDELCOLOR offers a choice between a 'smooth' CLUT (a gradual change of hue with dwell) and a 'contrast' CLUT (7 hues, each changing intensity in 10 steps). The smooth CLUT tends to highlight areas lying near to the Set and contrast them to a more uniform background color over the rest of the field, due to the rapid increase in the rate of dwell change as you approach the Set—while the contrast CLUT reveals structure lying far from the Set. Given only two CLUTs, these two are optimum choices, revealing quite different aspects of the Set while providing attractive images. The other two programs in this category simply offer the ImageWriter colors as an additional CLUT option.
3. Individual adjustment for each dwell (MANDELBROT MICROSCOPE, MEGABROT, ANI–MANDEL, MANDELBROT 2.7). This feature would appear to be quite powerful—but in practice it is far too time–consuming to be very useful. Individual adjustment of 100 or 200 (or more) colors with the Color Picker is simply not a practicable way to set up an attractive image.
4. Adjustment over a range of dwells (MEGABROT, MANDELBROT 2.7). This is the most powerful adjustment method, since it allows the user to set up a complete CLUT involving a full range of colors in a comparatively short time. Basically, you select the end points of a range of dwells, and the program lets you select (with the Color Picker) the colors for those two end points, and then interpolates a 'smooth' CLUT between them. By picking subranges, and giving each subrange a single hue and a range of intensities, you can set up a 'contrast' CLUT. Note that MANDELBROT 2.7 can save and reload its color sets, which lets you try different color sets on a given image without having to recalculate the image.

Mandelbrot Set Color: It is conventional to represent points lying within the Mandelbrot Set as black, and all but two of these programs do so. The exceptions are MANDELBROT MICROSCOPE and MANDELZOT, which use white for this purpose. An earlier version of MANDEL8 (MANDEL881) used white as well, but the current version has switched to black. MANDELBROT 2.7, although its default color is black, allows the user to select any color for the Set.

Save Image: Plotting takes long enough that some means of saving images is an essential feature for a color Mandelbrot program. However, only MANDELCOLOR, MANDELBROT 2.7, and MANDELZOT have a working Save routine that lets you open and continue working on a saved file. When a saved image is loaded it is completely functional—one can use the drag rectangle to generate new screens. MANDEL8 has a Save routine which creates a PICT file—but the program cannot open files, and many color graphics programs I had available were not able to open the PICT file as anything other than a blank window (ATG Paint *will* open the file). MANDELBROT MICROSCOPE, as mentioned above, does not have a working Save routine that functions on my Macintosh II.

Save palette: MANDELBROT MICROSCOPE and MANDELBROT 2.7 can save the color setup and reload it, thus instantly changing the working palette of colors.

Multiple windows: MANDEL8, MANDELCOLOR, and MANDELZOT can have more than one window up at the same time, letting you see simultaneous views of different magnifications or different regions of the set.

Large screen: All but three of these programs provide support for large screens (>640x480 pixels), using standard growable windows (MANDEL8, MANDELZOT), an automatic full–screen fixed window (ANI–MANDEL), or fixed windows whose size is set in a dialog box (MANDELCOLOR). MEGABROT, MANDELBROT MICROSCOPE, and MANDELBROT 2.7 use a fixed display region and cannot take advantage of the extra pixels on large screens.

Background in MultiFinder: Even with direct math chip access, these programs will take a long time to compute screens at high dwell values. It is quite possible to have a single plot run for an hour or two if you are working at high magnification and near the Set boundary. The ideal Mandelbrot program would therefore run as a background task under MultiFinder, letting you use the Mac II for your normal work while the Mandelbrot screen continues to compute during any time it can grab a few CPU cycles without slowing down your main task. MANDELZOT and MANDELCOLOR are

the only programs in this group that will run in this manner, although MANDELCOLOR does some anomalous things with screen refreshing while it does so.

Refresh Screen: All but one of these programs (MEGA-BROT) refresh the screen correctly after DAs, screen savers, etc. The earlier version of MANDEL8, (MANDEL881) was also unable to refresh the screen.

Fixed r/i ratio: Most of these programs produce images with a fixed magnification *ratio* of 1 between the real–axis scale and the imaginary–axis scale for a given plot. MANDEL-COLOR maintains this linearity despite its ability to change the shape of the plotting window, which means that part of a region within the selection rectangle will not appear in the next plot unless the selection rectangle and the plotting window have identical aspect ratios. MANDEL8 and MAN-DELZOT, which both use standard growable windows, can produce a distorted image since the selection rectangle is completely mapped into the plotting window regardless of any difference in their aspect ratios.

Julia Set: The Mandelbrot Set is computed by iterating the equation $\mathbf{z} = \mathbf{z}^2 + \mathbf{c}$ for a fixed starting value of $\mathbf{z} = \mathbf{0}$, and letting **c** range over the complex plane. The Julia Set for a given point in the complex plane is found from the same equation, using a fixed starting value of **c** (which simply defines the location of the point in question) and letting **z** range over the complex plane. Computing the two sets is thus very similar, and it is very easy for the same program, with a few small modifications, to compute either set on demand. Surprisingly, only ANI–MANDEL gives the user this choice. You may select a 'seed' value (the starting value of **c**), and then also select values for the center coordinates and side length of the resulting plot. The color animation and color change features of the program work in the Julia Set mode.

Conclusion

As stated above, no one of these programs will answer to all needs. My personal preferences are MANDELCOLOR, MANDELBROT 2.7, and ANI–MANDEL—which, between the three of them, let me look at almost any aspect of the Mandelbrot and Julia Sets that I care to. A blend of the features of these three with the 'DivCon' routine and 18-place coordinate reporting from MANDELZOT, would be a very satisfactory Mandelbrot/Julia program.

An ideal Mandelbrot program would have the following features:

1. Mandelbrot and Julia Sets.
2. Direct access to the 68881 *and* the Mariani/Silver 'Div-Con' algorithm (as an option).
3. Magnification to the limit of the 68881 (approx. 30 quadrillion diameters).
4. Maximum dwell 4000 or greater.
5. Escape radius set by the user, over the range 2 ↔ 100 (and possibly less than 2).
6. Selection by both mouse (drag rectangle or click on center) and by typing coordinates (19 or 20 decimal places accepted).
7. Ability to both magnify and reduce the image, and to scroll the image as well.
8. Coordinate reporting (to 19 or 20 decimal places).
9. Full use of 8–bit color (254 colors) and possible expansion to more colors using 24–bit hardware.
10. Color animation (with stop, reverse, and single–step).
11. User–settable colors, preferably with routines for setting ranges of color as in MANDELBROT 2.7, and the ability to store and reload color setups. Easy generation of both 'smooth' and 'contrast' CLUTs is essential.
12. The ability to save and open (as working files) images in some standard (PICT 2?) format.
13. Full–screen plotting even on large screens.
14. Some method for faster plotting during exploration (small window or coarse pattern).
15. The ability to run as a background task under MultiFinder (while showing the progress of the plot if desired).
16. The ability to accept a math function of the user's choice to define a non–circular 'escape region'.

Several of these programs are currently under active development, and I expect that something very close to this ideal will be available in the not–too–distant future.

NON-GLOSSY STOCK

For those of you that disliked the glossy stock used in Amy #10: hooray, it's gone!

For those of you who liked it, I'll explain the relapse to non-glossy. Mainly, my new printer can't handle glossy on his press (too slippery). In addition, glossy is heavier, and pushes the weight of an eight page newsletter plus envelope over one ounce, thus increasing the first class mailing rate by 20¢. Also, the glossy paper costs more.

"THE ARMCHAIR UNIVERSE"

— Rudy Rucker

To learn computer programming one needs a few interesting problems to program *about*. Kee Dewdney's *The Armchair Universe* is a good source of visually interesting programs, including the Mandelbrot set and cellular automata. The book also includes chapters that are more in the nature of ideas for thought-programs that clarify such difficult issues as analog vs. digital computation, the busy bearer function, perceptrons, and more. The book gains much of its zest from the fact that Dewdney is — for lack of a better word — a maniac, prone to using the most surprising analogies and linguistic tropes. I plan to use the book as the text for my Advanced Programming class next semester.

CELLULAR AUTOMATA

A letter from Rudy Rucker (July 13, 1988)

I've been working on cellular automata all winter, and have about a disk's worth of them running. I hope to write a book to go with the disk and to have the package on the shelves by 1990. Anyone who wants to see the current version (1.1) can get a copy by sending me $10 [see address at end]. My friend (and fellow science-fiction writer) Charles Platt is selling his own highly interactive cellular automata programs as well as [version] 1.0 of my disk. I understand that he bought the Amygdala mailing list, so readers will be hearing from him.

The similarity between cellular automata and the Mandelbrot set is that in both cases one has intricate patterns arising from the process of submitting a seemingly simple definition to a lot of iterative computation. As I explain in my book Mind Tools, the objects produced have what information-theorists call "low complexity and high depth." To me this seems like the way in which living organisms develop — an oaktree from an acorn, a chicken from an egg.

While I'm on the subject of cellular automata, I can't resist quoting a very remarkable passage from Thomas Mann's book, *Dr. Faustus.* The passage is about crystalline water-glass cultures (like the "magic stonegarden" kits one can buy in a dimestore), yet it could equally well be about CAs: simply replace the aquarium with a computer screen.

The vessel of crystallization was three-quarters full of slightly muddy water — that is. dilute water-glass — and from the sandy bottom there strove upwards a grotesque little landscape of variously coloured growths: a confused vegetation of blue, green, and brown shoots which reminded one of algae, mushrooms, attached polyps, also moss, then mussels, fruit pods, little trees or twigs from trees, here and there of limbs. it was the most remarkable sight I ever saw, and remarkable not so much for its appearance, strange and amazing though that was, as on account of its profoundly melancholy nature. For when [Jonathan] asked us what we thought of it and we timidly answered him that they might be plants: "No," he replied, "they are not, they only act that way. But do not think the less of them. Precisely because they do, because they try as hard as they can, they are worthy of all respect."

He exposed the aquarium to the sunlight, shading three sides against it, and behold, toward that one pane through which the light fell, thither straightway slanted the whole equivocal kith and kin: mushrooms, phallic polyp-stalks, little trees, algae, half-formed limbs. Indeed they so yearned after warmth and joy that they actually clung to the pane and stuck fast there.

"And even so they are dead," said Jonathan, and tears came in his eyes, while Adrian, as of course I saw, was shaken with suppressed laughter.

A longer excerpt of my story on the M object [see Amygdala #8, page 6] appeared in the last issue of Nick Turner's magazine, *The Terra Nova Letter*, available from Nick for $1 at 235 Embarcadero Rd., Palo Alto, C 94301. The full finished story, called "As Above, So Below," will appear this fall in *The Microverse*, a coffee-table anthology edited by Byron Preiss.

One last remark about cellular automata. Everyone knows the two-state two-dimensional rule called *Life*, but there is an equally interesting rule called *Brain.* In both rules, a cell is thought of as having eight neighbors: the four cells which share a side, and the four which share a corner. Invented by Brian Silverman, *Brain* is a two-dimensional cellular automaton with three states: 0. 1, and 2. Each cell in a two dimensional grid (I have 50x80 and 200x320 versions on my disk) simultaneously updates its state as follows. If you are in state 1 you go to state 2. If you are in state 2 you go to state 0. If you are in state 0, you sum up the number of neighbor cells that are in state 1. If the sum is two then you change to state 1, otherwise you stay in state 0.

Brain is both very active and very stable. Unlike *Life* it tends not to die down to repetitive blocks and blinkers. Yet its activity is not seethingly chaotic. Whether started with a few lit cells or a lot of them, *Brain* usually stabilizes with about 10% of the screen cells filled by moving patterns. Most patterns move vertically or horizontally at a speed of one cell per update, but there is a special configuration called the Butterfly which, analogously to *Life's* glider, moves at 45 degrees at a speed of one cell per four updates. My biggest find to date is a *Brain* pattern which shoots out Butterflies: I call it the Butterfly Gun, and it appears on version 1.1 of my disk. Given the existence of a Butterfly Gun, it seems likely that *Brain* can be proved computationally universal as was *Life.*

I hope that some other readers write in about cellular automata as well!

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RS: The Thomas Mann material also brings to mind the hallucinographical images created on a computer by Japanese artist Yoichiro Kawaguchi, as depicted and discussed in his book *Growth Morphogenesis.*

FRACTAL SOFTWARE REVIEWER

If you have fractal software for the *Atari ST* and you'd like it mentioned or reviewed in *Amygdala,* send it to:

Curtis H. Hoffmann
PO Box 8495
Minneapolis, MN 55408

See his review *FRACTAL PROGRAMS FOR THE ATARI ST*, below.

Curtis H. Hoffmann, 31, is a science fiction author with one book already published — *Project: Millenium* — and

three more in the works. He has done programming and stand-up comedy, and graduated from the University of Minnesota with a BSEE. Currently he is doing contract software documentation, and hopes to set up a neon sign shop soon.

If you want copies of Atari ST material mentioned or reviewed in these pages, request it from him (cost is up to him).

FRACTAL PROGRAMS FOR THE ATARI ST

Welcome to the first Atari ST PD fractal software review. Starting off quickly, there is LANDSCAP.PRG by Frank Mathy, no address given. This is a medium-res, mouse-driven fractal generator that creates green mountains and islands, and blue lakes or stretches of ocean. It doesn't have much scope, the landscape isn't solid, and the pictures can't be saved, but its redeeming feature is: it's based on a triangular pattern that, with some warping during the iteration process, produces almost realistic 3-D landmasses.

FRACT3D.PRG, version 122385, was written by Patrick Bass. FRACT3D is a Mandelbrot generator that can churn out 2-D or 3-D fractals with peaks and potholes. It's slow, of course, but the program can be stopped in mid-picture and the data saved to disk. Since it's mouse-driven, setting up the starting conditions is cumbersome, and the preset color selection does not always do the pictures justice. However, it is good at displaying Mandelbrot fractals in medium resolution.

BIBLIOGRAPHY

Thomas Bank has resigned as Amygdala bibliographer. Readers of Amygdala should now submit article and book bibliographic entries directly to **Amygdala** to be added to the list.

117 sent in by Wm R Davis and Ian Entwistle.

119 sent in by Howard A Ashley.

110. RS Keller, **"The Binary Forest",** *Home Computer Magazine* (Aug 1984) 41-43. [Logo program to create fractal trees which grow leaves. For Apple II, Commodore 64, IBM PC. Demonstrates concept of fractals.]

111. S Begley, **"Finding Order in Disorder",** *Newsweek* (Dec 21, 1987) 55-56. ["The science of chaos reveals nature's secrets." includes three color pix taken from TBF.]

112. MF Barnsley & AD Sloan, **"A Better Way to Compress Images",** *BYTE* (Jan 1988) 215-223. ["Mathematics is providing a novel technique for achieving compression ratios of 10,000 to 1 — and higher." Also see review in Amygdala #10]

113. MF Barnsley & S Demko, **"Iterated Function Systems and the Global Construction of Fractals"**, *The Proceedings of the Royal Society of London* (A399, 1985) 243-275.

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116. J Elton, **"An Ergodic Theorem for Iterated Maps"**, *Journal of Ergodic Theory and Dynamical Systems.* Forthcoming.

117. A Fedonczuk, **"Mandelbrots in Moments"**, *Acorn User* (Mar 1988) 103-107, 122-124. [Fedonczuk's "Mandelbrot" program runs on the Archimedes micro. It can calculate 64K pixels in under 30 seconds, using 256 colors. It allows you to zoom into the set using the mouse, and expand or shrink a box around the area by pressing buttons. The computer is based on the Acorn RISC Machine, or ARM, described in detail by Peter Cockerell in Acorn User for June 1987. The program's inner loop is written in ARM machine code. The program listing8, both BASIC and assembler, is given on pages 122-124.]

118. C Pickover, **"From Noise Comes Beauty"**, *Computer Graphics World* (Mar 1988) 115-116. ["Textures reminiscent of rug weavings and wood grains spring from simple math formulas." These patterns arise from an array of random numbers subject first to a local averaging operation, then a contour enhancing operation using a sinusoidal function. Finally the image is halftoned using damped error diffusion. Several B/W pictures accompany the article.]

119. SJ Taylor, **"The measure theory of random fractals"**. *Math. Proc. Cambridge Philos. Soc. (GB)* (Nov. 1986) 383-406. [The author gives a brief review of the measure theory of random fractals.]

COMMERCIAL PRODUCTS

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